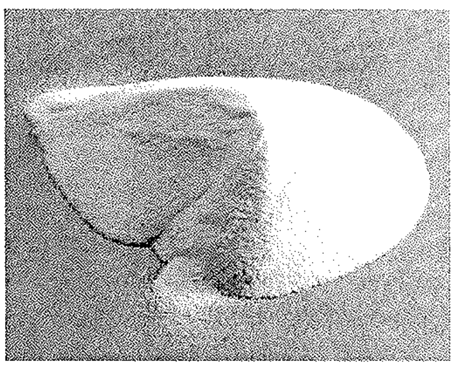
Full contour zirconia enraptures the industry.

A Changing Direction in Dentistry: Full-Contour Zirconia

By Robin A. Carden

Zirconia is one of the most studied ceramic materials in the world for uses ranging from telecommunications to the new energy of the future to environmentally-friendly products. In clinical dentistry, it is widely used for the fabrication of crown copings, bridge frameworks and custom implant abutments. Its durability, biocompatibility, natural esthetics and low cost when compared to alternative restorative materials make it the ideal solution for a variety of clinical applications. More recently, dental use is trending toward full-contour (monolithic) zirconia — that is, solid zirconia restorations with no porcelain overlay. Ongoing material advancements have produced the strongest and most reliable all-ceramic restoration to date, making zirconia an ideal alternative solution wherever traditional metal or PFM restorations might be prescribed.

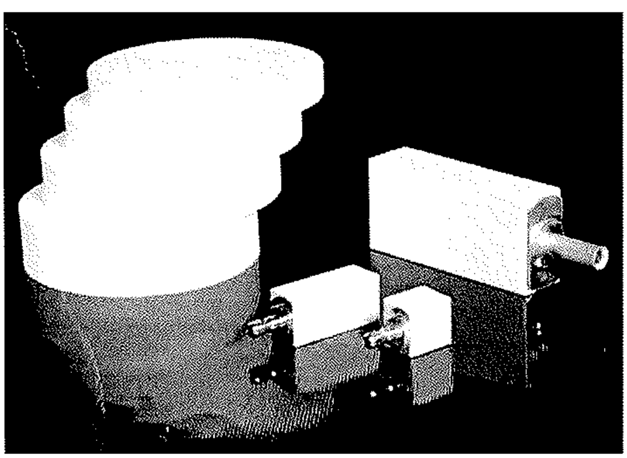


Material Origins

Zirconia, or zirconium oxide, is the common name for the chemical compound zirconium dioxide (ZrO_2). The material is commercially available in two basic forms. The first of these is naturally derived from the mineral Baddeleyite. The second is synthetically derived from zircon sand ($ZrSiO_4$) using a solid state reaction process. Several oxides such as magnesium oxide (MgO), yttrium oxide (Y_2O_3), calcium oxide (CaO), cerium (III) oxide (CE_2O_3), and others are added to zirconia in order to stabilize the tetragonal and/or cubic phases. The resulting material, often referred to as yttria-stabilized zirconia (YSZ), exhibits superior strength and flexibility, surpassing the mechanical limitations of traditional fine ceramics.

Figure 1 *(Above)* Zirconia Powder

Figure 2 *(Right)* BruxZir Blanks



Material Advantages

The fast-growing popularity of full-contour zirconia is easy to understand when observing several material advantages:

1. **High Flexural Strength** — Full-contour zirconia products on the market today boast flexural strength ranging anywhere from 850MPa to 1,465MPa. These higher-level strength increases have been achieved through the use of post-powder processing. When compared to the flexural strength of porcelain ceramics, with typical ranges of 71MPa (feldspathic porcelain) to 419MPa (In-Ceram), the zirconia strength advantage becomes clear.
2. **High Fracture Toughness** (K1C Value) —Strength and toughness are not necessarily related. Brittle materials may exhibit significant tensile strength by supporting a

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static load, whereas toughness indicates how much energy a material can absorb before mechanical failure. Also thought of as impact resistance, fracture toughness is a quantitative property that describes the ability of a material with inherent microstructural flaws to resist fracture via crack growth and propagation. A piece of lead or steel has high fracture toughness and will generally encounter ductile fracture, characterized by extensive plastic deformation prior to structural failure. Materials such as glass and traditional glass-ceramics typically exhibit low and inconsistent fracture toughness, and are prone to brittle fracture, characterized by a lack of apparent plastic deformation prior to structural failure. Thus, fracture toughness becomes one of the most important properties of any brittle material for virtually all design applications. The fracture toughness for partially stabilized zirconia is naturally high because of an internal mechanism that actually inhibits crack propagation. Inside, cubic grains are constraining the tetragonal precipitates that want to expand and release associated energy. When these grains are faced with a propagating crack tip, the tetragonal phase is released and allowed to change back to the more stable monoclinic phase. This results in an associated volumetric expansion, effectively closing the advancing crack. Known as phase transformation toughening, this unique self-healing event gives partially stabilized zirconia a fracture toughness that is three to six times higher than normal zirconia and most other ceramics. Even so, ongoing methods are being devised to modify the yield strength, ductility and fracture toughness of both crystalline and amorphous materials, including zirconia. For instance, consolidation processes are being used to reduce grain size. Because crack propagation through a material's grain boundaries is deflected by the material's grains, a material consisting of smaller grains becomes inherently stronger, as there are more grains to absorb energy from the force of the crack.

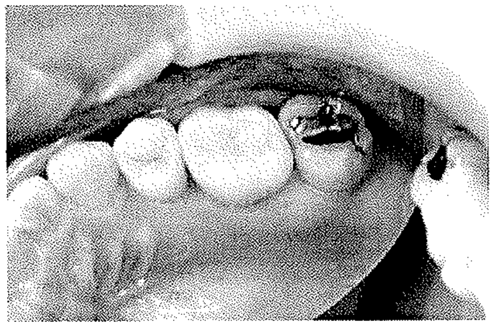

Figure 3 *(Left)*
Monicap BruxZir

Figure 4 *(Below)*
Monicap Full Cast

Whereas a crack in a traditional ceramic travels all the way through the material with little inhibition, transformation toughening represents a breakthrough in achieving all-ceramic materials with a high value for fracture toughness. Today's partially stabilized zirconia is so tough that it can be struck with a hammer or fabricated into a hammer for driving nails.

3. **Resistance to Thermal Shock** — Zirconia has relatively low thermal expansion numbers, giving it

Understanding Zirconia

Names: Zirconia, zirconium oxide, zirconium dioxide (ZrO2), yttria-stabilized zirconia (YSZ)

Terms:

Phase Transformation Toughening: The naturally occurring process by which cubic grains within stabilized zirconia constrain tetragonal precipitates, effectively closing advancing cracks and resulting in a sort of self-healing of the material.

Fracture Toughness: A property that describes the ability of a material with inherent microstructural flaws to resist fracture via crack growth and propagation.

Plasticity: The deformation of a material undergoing non-reversible changes of shape in response to applied forces.

Brittle Fracture: No apparent plastic deformation takes place before fracture.

Ductile Fracture: Extensive plastic deformation takes place, characterized by slow propagation and absorption of large amounts of energy, before fracture.

excellent resistance to thermal shock. This means it will remain very stable in the mouth and will face fewer stress factors resulting from expansion and contraction.

4. **Improved Esthetics** — If there has been a complaint regarding full-contour zirconia to date, it would be that its opaque white hue lacks the translucent, ivory shade of natural teeth. Zirconia can be stained and glazed to a prescribed tooth shade, but has still been limited by a lack of inherent translucency. However, consolidation processes in the laboratory that initially focused on improving strength through reduced particle size have led to related innovations in material translucency. These advancements, along with improved blending processes, allow the purest zirconia powder to be changed into an ivory shade that is more lifelike than the typical snow-white zirconia. Whereas full-contour zirconia is typically prescribed only for posterior restorations, newer clinical cases have shown it to blend in reasonably well with anterior teeth. These continuing enhancements in color and translucency, to go along with the elimination of dark gingival lines associated with traditional PFM restorations, give rising hope to full-contour zirconia becoming an acceptable anterior restorative.

5. **Improved Wear Compatibility** — Diamond-polishing a full-contour zirconia crown provides longterm life for opposing enamel surfaces. This wear compatibility has been validated in enamel wear in-vitro studies, and clinical studies are also under way. A 2010 comparative wear study conducted by professor Dr. J. Geis-Gerstorfer and sponsored by Glidewell Dental Laboratories used the Willytech Chewing Simulator to simulate the clinical performance of both BruxZir Solid Zirconia and Ceramco®3 porcelain over a period of five years. The reported findings stated that, after 1.2 million wear cycles under a load of 5 kg, the wear of the antagonist situation (Steatite ball) was found to be significantly lower with BruxZir (72 ± 21μm) than with Ceramco3 (110 ± 48μm).

6. **Cost** — A discussion of the benefits offered by full-contour zirconia would not be complete without mentioning cost factors. Despite its many material advantages, zirconia is considerably less expensive than traditional, precious metal.

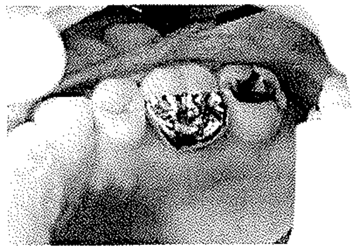

Figure 5 *(Above)*
Monicap Metal Occlusal

Indications

Full-contour zirconia is indicated for posterior crowns, crowns over implants and crowns with limited occlusal clearance. It is also indicated for full-arch bridges up to 14 units. Primary candidates include bruxers and grinders who do not desire cast gold or metal occlusal PFM restorations. For esthetic reasons, it is recommended that a facial veneer of porcelain be used on any zirconia-based anterior restoration. However, full-contour zirconia may be used in specific anterior cases where a dentist wishes to emphasize the strength of the restoration over its esthetics.

Availability

Commercially available zirconia blanks for in-lab milling include brands such as BruxZir, Sagemax HT, Crystal Diamond Zirconia, Zirlux, Prettau and Origin. Prescribed crowns include brands such as BruxZir, Suntech FC, Z-Brux, and TRICONia.

Due to its high flexural strength, high fracture toughness, resistance to thermal shock, metal-free esthetics and terrific wear compatibility, full-contour zirconia is an ideal material for dental restorations. It also boasts excellent contours and contacts for desired marginal fit, conventional chamfer prep and cementation, and affordability for both clinicians and their patients. Prescribed almost exclusively for posterior restorations, material advancements may make it an acceptable solution for some anterior restorations as well, further fueling its popularity as the material of choice for dental restorations today. **JDT**

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The *Journal of Dental Technology* and *JDT Unbound* have covered zirconia extensively. Search our archives at **www.jdtunbound.com** to find out more about this material.

About the Author:

Carden founded Talon Composites, the manufacturer of Talbor, a composite material that uses advanced ceramics and metals. To date, he holds more than 25 patents, mostly related to metal and ceramic composites. In 1998, he won the Design Engineering Award from Design News. He is also the inventor of the translucent orthodontic braces for 3M™ ESPE™ and Ceradyne Inc. Presently, he works at Glidewell Laboratories as senior director of research and development.